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Differences in Anthropometric Characteristics and Motor Abilities Between Youth Female Volleyball Players and Non-Athletes, and Their Interrelationships in the Total Sample

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Abstract

The aim of this cross-sectional study was to examine potential differences in body characteristics and motor abilities between young girls enrolled in a volleyball school and those not participating in any organized sports activities. Additionally, the study sought to investigate the relationships between anthropometric and motor parameters. The anthropometric evaluation included three morphological variables: body height (BH), body mass (BM), and body mass index (BMI). For the assessment of motor abilities in girls, a battery of standardized field tests was used, including the following tasks: Plate Tapping Test, Flying 20 m test, Japan Test, 2 kg seated medicine ball throw, Standing Broad Jump, 30-second sit-up test, 30-second squat test, shoulder rotation with stick test, and Side Steps test. The results of the Mann–Whitney U test indicate that volleyball players achieved significantly better results in most of the examined variables ($p<0.05$), particularly in speed, agility, explosive and repetitive strength, as well as coordination. The effect sizes, which were moderate to very large in most variables, suggest that the observed differences are not only significant but also practically meaningful, representing the outcome of a systematic and continuous volleyball training process. The correlation test revealed a strong relationship between body dimensions and strength-related tests, as well as pronounced interconnections among speed- and agility-related abilities. In contrast, flexibility appears to represent a relatively isolated motor component within the analyzed model. Based on the above findings, it can be concluded that volleyball, as a sports activity, represents an effective model of physical exercise for improving motor abilities and the overall physical development of girls.

Keywords: *morphological composition, motor performance, physical fitness, youth athletes, volleyball*

Introduction

Volleyball as a sport was developed in 1895 by William G. Morgan, director of physical education at Holyoke College in the state of Massachusetts, United States (Korjenić & Redžić, 2022).

Volleyball is an engaging, highly dynamic, and attractive sport in which the speed of ball movement during a match requires players to possess a high level of reaction speed and agility in order to control the ball effectively. Motor abilities, including coordination, explosive strength, agility, and speed, are among the key factors with a strong influence on volleyball performance (Ilić, Stojanović & Mijalković, 2023).

The development and improvement of motor abilities in female volleyball players represent an important aspect that can be enhanced through systematic training (Bompa, 2000). It is im-

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portant to note that training models differ between sexes due to psychophysical differences (Katić, Grgantov & Jurko, 2006). The technical and tactical demands of volleyball, frequent changes of direction in the frontal and sagittal planes, and various types of jumps require adequate general and sport-specific physical preparation, as well as well-developed technical skills adapted to specific playing positions (Martinović et al., 2011).

Volleyball is considered an asymmetrical sport, as elements such as serving and spiking are predominantly performed with the dominant arm. Within the four defined stages of a volleyball career, the second phase (ages 10–14) emphasizes the acquisition of technical and tactical elements, with particular importance placed on bilateral muscular development during this developmental period (Katić, Grgantov & Jurko, 2006). Nešić (2005) highlights that volleyball schools at this stage, focused on mastering fundamental technical and tactical elements, play a crucial role in the development of elite female volleyball players.

Based on recent studies, it is evident that numerous researchers have sought to determine whether differences exist in anthropometric characteristics and motor abilities between athletes and non-athletes (Bubanj et al., 2013; Cristina-Elena & Liliana-Elisabeta, 2014; Ivanović & Ivanović, 2013; Jenko-Miholić, Čižmek, & Peršun, 2010; Radu, Popovici, & Puni, 2015). Previous findings have generally shown that athletes achieve better results than non-athletes in both anthropometric parameters (Bubanj et al., 2013; Radu et al., 2015) and motor abilities (Cristina-Elena & Liliana-Elisabeta, 2014; Ivanović & Ivanović, 2013; Jenko-Miholić, Čižmek, & Peršun, 2010).

However, most of these studies focused on boys rather than girls, and the samples predominantly consisted of older adolescents, meaning athletes with relatively long training experience. Only one study was found that compared differences between female athletes and non-athletes (Radu, Popovici, & Puni, 2015). That study included older adolescent girls and was limited exclusively to anthropometric parameters.

Accordingly, there is a clear need for research examining differences in both anthropometric characteristics and motor abilities, specifically between volleyball players and non-athletes. Therefore, the aim of this study was to determine the differences in anthropometric characteristics and motor abilities between adolescent volleyball players and their non-athletic peers. Additionally, the study sought to investigate the relationships between anthropometric and motor parameters.

Methods

Participants

The sample consisted of 43 healthy girls. Among them, 23 girls with a mean chronological age of 12.48±0.85 years were active members of the volleyball club "Banja Luka" and had 2.08±0.84 years of training experience. The remaining 20 girls were students of the primary school "Holandija" – Slatina, with a mean chronological age of 12.25±0.97 years, and were not involved in any sports activities.

Procedures

Testing was conducted between March 7 and March 15, 2024. Prior to the start of testing, the participants performed a 15-minute warm-up. All tests were carried out under the same conditions. The participants were familiarized with the testing protocol in advance. Measurements and testing were conducted by coaches and physical education teachers. The study was conducted in accordance with the World Medical Association Declaration of Helsinki (2011), and the parents of the participants provided informed consent for the implementation of the testing.

Measurements

Anthropometric characteristics

Anthropometric measurements were conducted in accordance with an internationally recognized biological assessment protocol (Eston & Reilly, 2013). The evaluation comprised three morphological indicators: body height (BH), body mass (BM), and body mass index (BMI). Stature was determined using a portable stadiometer (Seca Ltd., Bonn, Germany) with a precision of 0.1 cm, while body mass was obtained with a Tanita body composition analyzer (Tanita®, model BC-418MA, Tokyo, Japan). Body mass index was subsequently derived using the conventional equation: BMI = BM (kg) / BH^2 (m^2). Given its strong association with adiposity levels, BMI is commonly applied as a practical marker of weight status in pediatric populations (Costill, Kenney, & Wilmore, 2008).

Motor abilities

Motor abilities were assessed using standardized field tests, with each test selected to evaluate a specific motor domain. Upper limb movement speed was evaluated using the Plate Tapping Test, sprint speed was assessed by the Flying 20 m test, and agility was measured with the Japan Test. Upper body explosive strength was determined by the 2 kg seated medicine ball throw, while lower body explosive strength was assessed using the Standing Broad Jump. Repetitive strength was evaluated through the 30-second sit-up test and the 30-second squat test. Flexibility was assessed by the shoulder rotation with stick test, and lower limb coordination was measured using the Side Steps test (Table 1). The given motor ability tests have been used in numerous studies (Gjinovci et al., 2025; Jovanović, Katanić, Trajković, Đorđević, & Stanković, 2025; Strukar, Harasin, & Gilić, 2025).

Table 1. Motor Ability Tests and Units

Motor Test	Motor Ability	Unit
Plate Tapping Test	Upper limb movement speed	seconds (s)
Flying 20 m test	Sprint speed	seconds (s)
Japan Test	Agility	seconds (s)
Medicine ball throw (2 kg)	Upper body explosive strength	meters (m)
Standing Broad Jump	Lower body explosive strength	centimeters (cm)
Sit-up test (30-second)	Repetitive strength (trunk)	repetitions (n)
Squat test (30-second)	Repetitive strength (lower limbs)	repetitions (n)
Shoulder rotation with stick	Flexibility	centimeters (cm)
Side Steps test	Lower limb coordination	repetitions (n)

Statistics

Descriptive statistics were calculated for all variables, and the normality of data distribution was examined prior to further analyses. Given the characteristics of the data, the Mann–Whitney U test was applied to determine differences between volleyball players and non-athletes. The effect size was calculated and presented using the coefficient r, in order to quantify the magnitude of the differences and to estimate the impact of volleyball training on the measured anthropometric and motor parameters.

For the analysis of relationships between motor abilities, Spearman's rank correlation coefficient was used. The strength of the correlations was interpreted according to Cohen's guidelines, with values of 0.10–0.29 considered small, 0.30–0.49 moderate, and ≥0.50 large.

All collected data were statistically processed using the software package Statistica 19.0 (StatSoft Inc., Tulsa, USA), along with Statistical Package for Social Sciences (SPSS), version 26.0 (SPSS Inc., Chicago, IL, USA). The level of statistical significance was set at $p<0.05$.

Results

The results in Table 2 show that volleyball players achieved higher values than non-athletes in almost all measured parameters, including anthropometric measures, speed, agility, explosive and repetitive strength, and lower limb coordination. The only exceptions were the flexibility measures, where the differences were minimal.

Tabela 2. Descriptive Statistics

	Volleyball players			Non-athletes		
	N	**Mean**	**SD**	**N**	**Mean**	**SD**
Age (years)	23	12.48	0.85	20	12.25	0.97
Years of training	23	2.08	0.84	20	0.00	0.00
Body mass (kg)	23	52.99	9.00	20	42.90	10.23
Body height (cm)	23	161.19	7.18	20	152.43	8.76
BMI	23	20.34	3.11	20	18.30	3.15
Plate Tapping Test	23	10.20	1.46	20	11.44	2.02
Sprint speed (s)	23	3.98	0.30	20	4.50	0.36
Agility Japan (s)	23	8.69	0.74	20	10.17	0.73
Medicine ball throw (cm)	23	267.70	40.96	20	211.63	41.44
Standing broad jump (cm)	23	159.09	20.34	20	138.10	19.63
Sit-up test 30 sec	23	24.30	3.76	20	17.35	3.25
Squat test	23	30.09	3.53	20	25.95	2.61
Shoulder rotation with stick	23	74.17	15.74	20	78.11	15.07
Side Steps	23	10.87	0.81	20	12.64	1.30

Legend: N – number of samples, Mean – mean value, SD – standard deviation

Significant differences (Table 3) were found in favor of the volleyball players in the following variables: body weight ($p=0.001$; $r=0.486$) – moderate to large effect, body height ($p=0.003$; $r=0.457$) – moderate to large effect, and BMI ($p=0.028$; $r=0.334$) – moderate effect. Higher ranks among the volleyball players indicate that they are, on average, taller and heavier, which is consistent with the specific demands and selection criteria in volleyball.

The results show that volleyball players are significantly faster and more agile, with particularly pronounced differences in sprint speed and agility, which represent key abilities in volleyball: upper limb movement speed ($p=0.021$; $r=0.325$) – moderate effect, sprint speed ($p=0.000$; $r=0.646$) – large effect, and agility ($p=0.000$; $r=0.735$) – very large effect.

Similarly, significant differences in favor of the volleyball players were recorded in all strength tests: upper body explosive strength ($p=0.000$; $r=0.585$) – large effect, lower body explosive strength ($p=0.002$; $r=0.466$) – moderate to large effect, repetitive trunk strength ($p=0.000$; $r=0.747$) – very large effect, and repetitive lower limb strength ($p=0.000$; $r=0.581$) – large effect.

Additionally, lower limb coordination showed a significant difference in favor of the volleyball players ($p=0.000$; $r=0.635$), with a large effect size, which is consistent with the complex movements and frequent changes of direction characteristic of volleyball.

In contrast to these findings, no significant difference was observed between the groups in flexibility ($p=0.526$; $r=0.097$), indicating that volleyball training did not have a decisive impact on this ability.

Table 3. Mann–Whitney U Test

	Group	N	Mean	U test	Z	Sig	r
Body mass (kg)	Volleyball players	23	27.70	99.000	-3.190	0.001	0.486
	Non-athletes	20	15.45				
Body height (cm)	Volleyball players	23	27.73	107.000	-2.995	0.003	0.457
	Non-athletes	20	15.85				

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Table 3. Mann–Whitney U Test

	Group	N	Mean	U test	Z	Sig	r
BMI	Volleyball players	23	25.91	140.000	-2.191	0.028	0.334
	Non-athletes	20	17.50				
Plate Tapping	Volleyball players	23	17.87	135.000	-2.131	0.021	0.325
	Non-athletes	20	26.75				
Sprint speed (s)	Volleyball players	23	14.43	56.000	-4.238	0.000	0.646
	Non-athletes	20	30.70				
Agility Japan (s)	Volleyball players	23	13.39	32.000	-4.822	0.000	0.735
	Non-athletes	20	31.90				
MBT(cm)	Volleyball players	23	28.85	72.500	-3.836	0.000	0.585
	Non-athletes	20	14.13				
SBJ (cm)	Volleyball players	23	27.46	104.500	-3.057	0.002	0.466
	Non-athletes	20	15.73				
Sit-up test	Volleyball players	23	30.72	29.500	-4.899	0.000	0.747
	Non-athletes	20	11.98				
Squat test	Volleyball players	23	28.76	74.500	-3.809	0.000	0.581
	Non-athletes	20	14.23				
Shoulder rotation	Volleyball players	23	20.87	204.000	-0.634	0.526	0.097
	Non-athletes	20	23.30				
Side Steps	Volleyball players	23	14.57	59.000	-4.164	0.000	0.635
	Non-athletes	20	30.55				

Legend: N – number of samples, Z – approximation value, Sig – level of significance, r – effect size, BW – Body Weight, BH – Body Height, BMI – Body Mass Index, Plate – Plate Tapping, Sprint – Sprint Test, Agility – Agility Test, MBT – Medicine Ball Throw, SBJ – Standing Broad Jump, Sit-up – Sit-up Test, Squat – Squat Test.

The correlational analysis (Table 4), conducted on the total sample, revealed clear and systematic relationships between anthropometric characteristics and motor abilities. Body weight (BW) was strongly and positively associated with body height (BH; r=0.721, p<0.001) and BMI (r=0.835, p<0.001), whereas body height was not significantly related to BMI (r=0.271, p=0.079)

With respect to motor abilities, greater body weight and height were associated with better performance in explosive strength tests, particularly in the medicine ball throw (BW: r=0.565; BH: r=0.621; p<0.001) and, to a lesser extent, in the standing broad jump (BH: r=0.348, p=0.022). BMI showed a moderate positive correlation with the medicine ball throw (r=0.342, p=0.025). At the same time, body weight and height were negatively correlated with upper limb speed (plate tapping; BW: r=-0.451, p=0.002; BH: r=-0.328, p=0.032), indicating that participants with larger body dimensions achieved shorter completion times (i.e., better performance).

Table 4. Correlation Between Anthropometric and Motor Performance Variables

	BW	BH	BMI	Plate	Sprint	Agility	MBT	SBJ	Sit-up	Squat	SR
BH	0.721**										
	0.000										
BMI	0.835**	0.271									
	0.000	0.079									
Plate	-0.451**	-0.328*	0.359*								
	0.002	0.032	0.018								
Sprint	-0.211	-0.255	-0.122	0.205							
	0.174	0.099	0.436	0.186							
Agility	-0.294	-0.327*	-0.161	0.265	0.754**						
	0.056	0.032	0.301	0.086	0.000						
MBT	0.565**	0.621**	0.342*	-0.355*	-0.488**	-0.640**					
	0.000	0.000	0.025	0.019	.0001	0.000					
SBJ	0.251	0.348*	0.102	-0.115	-0.506**	-0.719**	0.606**				
	0.104	0.022	0.517	0.65	0.001	0.000	0.000				

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Table 4. Correlation Between Anthropometric and Motor Performance Variables

	BW	BH	BMI	Plate	Sprint	Agility	MBT	SBJ	Sit-up	Squat	SR
Sit-up	0.373*	0.230	0.301	-0.191	-0.550**	-0.745**	0.527**	0.579**			
	0.014	0.138	0.050	0.221	0.000	0.000	0.000	0.000			
Squat	0.169	0.204	0.049	-0.271	-0.563**	-0.696**	0.513**	0.487**	0.524**		
	0.278	0.191	0.753	0.079	0.000	0.000	0.000	0.001	0.000		
SR	-0.019	0.201	-0.160	0.062	-0.131	0.029	0.038	0.044	-0.167	-0.052	
	0.901	0.197	0.307	0.693	0.404	0.855	0.809	0.777	0.286	0.739	
SS	-0.318*	-0.353*	-0.181	0.230	0.614**	0.855**	-0.596**	-0.653**	-0.754**	-0.603**	0.155
	0.038	0.020	0.246	0.138	0.000	0.000	0.000	0.000	0.00	0.000	0.322

Legend: BW – Body Weight, BH – Body Height, BMI – Body Mass Index, Plate – Plate Tapping, Sprint – Sprint Test, Agility – Agility Test, MBT – Medicine Ball Throw, SBJ – Standing Broad Jump, Sit-up – Sit-up Test, Squat – Squat Test, rs – Spearman's Correlation Coefficient, p – Significance Level.

Speed and agility tests demonstrated strong interrelationships. The 20 m sprint (Flying) was highly correlated with agility assessed by the Japan test (r=0.754, p<0.001), as well as with lower limb coordination measured by the side steps test (r=0.614, p<0.001). The Japan test showed an exceptionally strong association with the side steps test (r=0.855, p<0.001), confirming their functional similarity in assessing agility and coordination.

Explosive strength (medicine ball throw and standing broad jump) was significantly associated with repetitive strength of the trunk and lower limbs (sit-up and squat tests; r=0.487–0.579, p<0.001), while simultaneously showing negative correlations with speed and agility tests (e.g., medicine ball and Japan test: r=-0.640, p<0.001; standing broad jump and Japan test: r=-0.719, p<0.001). Repetitive strength also demonstrated strong negative associations with sprint and agility performance (sit-up and Japan: r=-0.745; squat and Japan: r=-0.696; p<0.001).

Flexibility (stick rotation test) did not show significant correlations with most of the examined parameters, indicating its relative independence from other motor and anthropometric variables in this sample.

Overall, the findings suggest a strong relationship between body dimensions and strength-related tests, as well as pronounced interconnections among speed- and agility-related abilities, whereas flexibility appears to represent a relatively isolated motor component within the analyzed model.

Discussion

The aim of this study was to examine potential differences in body characteristics and motor abilities between young girls enrolled in a volleyball school and those not participating in any organized sports activities, as well as to investigate the relationships between anthropometric and motor parameters. The main findings showed that female youth volleyball players achieved significantly better performance in most motor variables, particularly in speed, agility, explosive and repetitive strength, and coordination, with effect sizes indicating practically meaningful differences. Additionally, strong correlations were found between body dimensions and strength-related tests, as well as clear interrelationships among speed- and agility-related abilities.

Based on the analysis of anthropometric characteristics, it was found that volleyball players demonstrated higher values in body height, body mass, and BMI, which is fully consistent with previous findings by Radu, Popovici, and Puni (2015), who also reported that female volleyball and handball players possess greater height and body mass than non-athletes. It is well established that success in volleyball largely depends on players' morphological characteristics, with body height and mass being key factors relative to the athletes' age (Marelić, Đurković, & Rešetar, 2008). The influence of anthropometric characteristics on motor abilities in volleyball players has also been demonstrated (Stamm, Veldre, Stamm, Thomson, Kaarma, Loko, & Koskel, 2003; Stamm, Stamm, & Koskel, 2006). In terms of competitiveness, these results may reflect a selection process favoring taller girls in volleyball clubs.

The results of the Mann–Whitney U test indicate that volleyball players achieve significantly better results in most motor variables, particularly in speed, agility, strength, and coordination, with moderate to very large effect sizes reflecting the impact of systematic training. These findings align with previous studies, which also reported that athletes outperform non-athletes in most motor tests (Cristina-Elena & Liliana-Elisabeta, 2014; Ivanović & Ivanović, 2013; Jenko-Miholić, Čižmek, & Peršun, 2010). While volleyball players were slightly more flexible, training did not produce a significant difference between volleyball players and non-athletes, suggesting that observed differences in other variables are primarily due to sports training rather than biological factors (Lazić, 2016).

The spike is a technical skill developed in training that initiates acceleration of the shoulder region (regio deltoidea) in volleyball players (Reeser, Fleisig, Bolt, & Ruan, 2010), which may explain the significantly greater upper limb speed in volleyball players compared to non-athletes. Strength is considered a fundamental motor quality in volleyball, initially developed through spontaneous and dynamic play in children and gradually directed toward structured training with external resistance (Sheppard, Nolan, & Newton, 2012). Strength has broad functional effects, contributing to endurance development, overall athletic performance, and injury prevention (Hughes, Ellefsen, & Baar, 2018). Training loads and repetitions vary depending on the targeted adaptations, promoting muscle hypertrophy and repeated force production, which explains the observed differences in repetitive strength between groups (Schoenfeld, Grgic, Van Every, & Plotkin, 2021). Upper and lower body strength are critical for optimizing athletic performance, as improved strength also enhances speed and agility during play (Martin, Gavra, & Martin-Hadmaş, 2024).

The development of serving skills in volleyball players is primarily aimed at optimizing service effectiveness, emphasizing not only execution speed but also increased muscle strength under isokinetic conditions, achieved through concentric muscle contractions (Telles, Cunha, Yoshimura, Pochini, Ejnisman, & Soliaman, 2021). Simultaneously, enhanced upper limb strength is crucial for effective service reception, as it relates to the ability to generate maximal muscle contractions (Pawlik, Dziubek, Rogowski, Struzik, & Rokita, 2022). Training in service execution and reception, as key technical elements of volleyball, likely explains the significantly higher upper limb strength observed in volleyball players compared to non-athletes.

Significant differences in speed, agility, and lower limb coordination between groups can be attributed to sport-specific training, which predominantly influences locomotor patterns in the horizontal plane, characterized by rapid changes of direction (forward-backward, lateral left-right) (Nešić, Ilić, Majstorović, Grbić, & Osmankač, 2013). These specific horizontal agility models in volleyball likely contributed to the development of explosive strength in the lower limb extensors (hip, knee, and plantar flexors), resulting in significantly better standing broad jump performance in volleyball players compared to non-athletes (Farac, 2024).

Regarding the relationships between anthropometric characteristics and motor abilities, the correlation analysis highlights the significant influence of anthropometric characteristics on motor performance in young female volleyball players. Greater body weight and height were associated with superior performance in strength tests, particularly the medicine ball throw and, to a lesser extent, the standing broad jump. This suggests that larger body dimensions provide a mechanical advantage in tasks requiring force production. Interestingly, body size was negatively correlated with upper limb speed, indicating that participants with higher body mass and height completed the plate tapping task faster, which may reflect the integration of strength and coordination in upper limb movements. These findings are consistent with previous research emphasizing the role of body morphology in determining athletic performance, particularly in sports such as volleyball, where height and strength are critical for effective execution of technical elements (Stamm et al., 2003; Marelić et al., 2008).

The established relationships between motor abilities, particularly explosive strength, speed, and agility, are consistent with previous findings (Banda, Beitzel, Kammerer, Salazar, & Lockie, 2019; Lockie et al., 2014; Nejić et al., 2025). This suggests that these motor abilities share common underlying neuromuscular and coordinative mechanisms, especially those governing rapid changes of direction and lower-limb force production. Lockie et al. (2014) identified a strong link between jump test performance and sprint acceleration in athletes, while Banda et al. (2019) suggested that enhanced jump performance may contribute to improved sprint capabilities. Additionally, Nimphius et al. (2010) emphasized that acceleration capacity underpins both linear and multidirectional movements, further highlighting the importance of developing explosive strength and agility in young athletes. In contrast, explosive and repetitive strength tests showed negative associations with speed and agility, indicating a trade-off between maximal force production and movement velocity. Flexibility appeared largely independent of other motor and anthropometric variables, confirming its role as a distinct motor component that is less influenced by body size or strength capacities. Overall, these relationships emphasize the complex interplay between anthropometric characteristics and motor abilities.

Limitations and Future Directions

Some of the main limitations of this study relate to the small sample size, particularly the small sub-samples, which limit the generalizability of the findings. Therefore, future research should include larger samples to enable broader generalization of the results. Additionally, although valid measurement instruments previously used in other studies were applied, future studies should incorporate more advanced measurement equipment to allow for a more detailed assessment of body composition and motor performance in girls.

Conclusion

The findings of this study indicate that young female volleyball players demonstrate significantly better performance in most motor variables compared to their non-athletic peers, particularly in speed, agility, explosive and repetitive strength, and coordination. The moderate to very large effect sizes confirm that these differences are not only statistically significant but also practically meaningful, reflecting the impact of systematic and continuous volleyball training. Furthermore, strong associations were identified between body dimensions and strength-related abilities, as well as among speed- and agility-related variables, while flexibility appeared to be a relatively independent motor component. Overall, the results suggest that volleyball represents an effective model of physical activity for enhancing motor abilities and supporting the overall physical development of girls.

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Conflict of interest
The authors declare no conflicts of interest.

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